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Probing Interstellar Dust With Space-Based Coronagraphs

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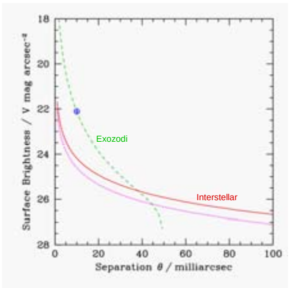
Summary

- TPF-C will be able to detect the light scattered by interstellar grains along lines of sight passing near Galactic stars.
- The relative flux of scattered light within 1" of a star at 100 pc in a uniform ISM of 0.1 atoms cm^{-3} is 10^{-7}. The halo grows in strength with the distance to the star and is unlikely to limit planet detection around the nearest stars.
- Grains passing within 100 AU of Sun-like stars are deflected by radiation, gravity and magnetic forces, causing scattered light features that reveal the stellar wind strength, magnetic field orientation and motion relative to the surrounding ISM.

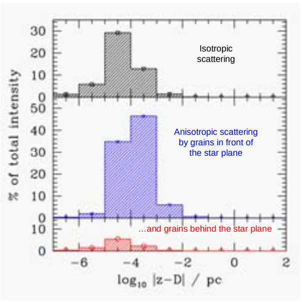
Results

1. Integrating the radiative transfer equation in a uniform interstellar medium including anisotropic scattering with a Draine (2003) phase function yields a scattered-light halo with fractional flux

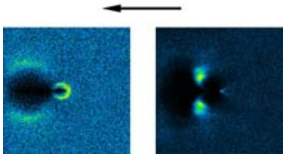
$$\frac{F(\theta_{\max})}{F_*} = 8\times 10^{-8}\left(\frac{n}{0.1\ \mathrm{cm}^{-3}}\right)\left(\frac{D}{100\ \mathrm{pc}}\right)\left(\frac{\theta_{\max}}{1''}\right).$$



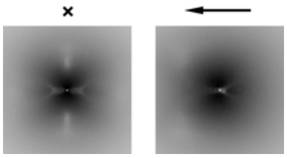
2. Surface brightness of an exozodi cloud (dashed) and uniform interstellar grains, scattering isotropically (dotted) or anisotropically (solid). A crossed circle marks the approximate angular separation and surface brightness of an exo-Earth at the nominal TPF-C angular resolution (Levine et al. 2006). The star lies at 100 pc.



3. Contribution to the surface brightness from grains at different locations along the line of sight passing 100 mas from the star in fig. 2. The three panels show isotropic scattering (top) and anisotropic scattering by grains in front of (center) and behind the star plane (bottom). Most of the light is scattered into our line of sight by grains within 100 AU of the star.



4. Interstellar dust density near a Sun-like star. The star is at center and the dust enters from the right (arrow). At left is an equatorial slice and at right is the polar plane holding the velocity vector. The images are 400x400 AU. Focusing by the stellar gravity, radiation and magnetic forces enhances the dust density up to 6x at left and 15x at right.



5. Model images of the starlight scattered by 0.1um grains round a Sun-like star at 100 pc. The star is viewed looking upstream (left) and from the side (right). The cross and arrow indicate the flow of the approaching grains. The images are 2 arcsec or 200 AU across, and were divided by the profile for uniformly-distributed dust. Dark regions show a deficit of scattered light where magnetic and radiation forces exclude particles near the star. The gray scale is linear between the minimum brightness ratio of about 0.1 (black) and the maximum of unity (white).

Significance

- High-contrast imaging will enable a new kind of measurement for probing interstellar dust and stellar winds.
- About 800 stars are potential targets, having V<5 and distances 20-100 parsecs, so their scattered light features fall in the clear aperture of the proposed coronagraph. Prime candidates lie in dense interstellar clouds with n>10 atoms cm^{-3}.
- Starlight scattered by interstellar dust will not affect the direct detection of Earth-like planets around the nearest stars, which are found mostly in the low-density local interstellar bubble.

References

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Levine M., Shaklan S. & Kasting J. 2006, Terrestrial Planet Finder Coronagraph - Science and Technology Definition Team Report, JPL publication D-34923.
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